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Effect of Replacing Fishmeal with Ground nut Cake on Growth, Feed Conversion and Carcass Composition of Fingerling *Oreochromis niloticus* (Nile Tilapia)

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Abstract
In this study, firstly proximate composition and fatty acid profile of oilseed meal used in fish feeds were analyzed and then feasibility of replacing fishmeal with ground nut cake for Nile tilapia *Oreochromis niloticus* fingerling by replacing 0% control diet, 20%, 40%, 60%, 80% and 100% fishmeal protein by ground nut oil cake protein was worked out. Fish were stocked at the rate of 20 per tanks in triplicate groups. *Oreochromis niloticus* fingerlings (0.57±0.02g; 3.49±0.12 cm) were fed the experimental diets near to satiation for 6 weeks. Diets used in this experiment contained 35% CP and 16.53 $kJ.g^{-1}$ GE, replacement of fish meal by groundnut oil cake on protein to protein basis was found to be feasible up to 20% as evident by insignificant differences (p<0.05) among the absolute weight gain (2.56±0.05 g/fish), feed conversion ratio (1.68±0.01), protein efficiency ratio (1.70±0.02) and specific growth rate (3.45±0.02%) of fish fed diet 2. However, further replacement of fish meal by ground nut cake protein beyond 20% resulted in a marked decrease (P<0.05) in above parameters.

Keywords: Growth performance, Ground nut, Requirment and *Orechromis niloticus*

Introduction
Tilapias have become one of the most important fish species for aquaculture and play an increasing role in the international aquatic food trade. Therefore, the development of cost effective feeds using inexpensive and locally available plant and animal protein sources will contribute to sustainable aquaculture development for the future (Mazid et al., 1997; Nguyen, 2007; Mzengereza et al., 2014; Yakubu et al., 2014; Pai et al., 2016; Jewel et al., 2018; Limbu, 2019). Tilapia are freshwater fish belonging to the family Cichlidae. They are native to Africa, but were introduced into many tropical, subtropical and temperate regions of the world during the second half of the 20th century (Pillay, 1990). Tilapia are currently known as "aquatic chicken" due to their fast growth, adaptability to a wide range of environmental conditions, disease resistance, high flesh quality, ability to grow and reproduce in captivity and feed on low trophic levels (El-Sayed 2006; Nguyen, 2007; Bhujel, 2014; Chirapongsatonkul et al., 2019). The aquaculture sector is developing more effectively than other food production sectors. However, economic factors such as

feed cost are blocking inhibiting development. Fish meal (FM) is the most attractive protein source for aquaculture diets because of its high protein content, well balanced amino acid and fatty acid composition, high digestibility and palatability, however, the high cost of FM and lack of availability are making it impracticable to use in all aquafeeds. In recent years, a decline in fish stocks on which FM production depends and the increased consumption of fish has promoted the search for alternative protein sources (Yıldırım et al., 2014).
Feed is the most expensive item, often ranging from 30 to 60 percent of the total variable expenses, depending on the intensity of the culture operation (Lim and Webster, 2006). Therefore, the development of cost-effective feeds using cheap and locally available plant protein sources has a great contribution to its sustainable aquaculture development in the future. In order to achieve this goal, the understanding of protein and essential amino acid requirements of tilapia is very important.

Tilapia, need a continuous supply of protein throughout life for maintenance, growth, and other physiological functions. Inadequate intake of protein will result in retardation or cessation of growth, or loss of weight due to the withdrawal of protein from less vital tissues to maintain the function of more vital ones. If too much protein is supplied, however, one part will be used to synthesize new tissue and the remainder will be converted to energy (NRC, 1983; NRC 2011; Prabu and Santhiya, 2016; Yousif et al., 2019a,b). Plant proteins are almost similar to FM in terms of the protein content and protein and amino acid digestibility (Hardy, 1996). However, their amino acid profile does not match the amino acid requirement of some fish species as FM does (Hardy, 1996; Mohammed et al. 2020). Fish meal is one of the most expensive ingredients in prepared fish diets. Fish nutritionists have tried to use less expensive plant protein sources to partially or totally replace fish meal (El-saidy and Gaber, 1997 & 2002).

Groundnut cake with crude protein content of 40-45% is a good supplement. It promotes growth and is palatable to fish. Groundnut cake protein is known to be deficient in lysine and methionine and also has a limited amount of tryptophan and threonine but amino acid quality improves in artificial diets when reinforced with lysine, methionine and tryptophan (Eyo and Olatunde, 1998; Yıldırım etal., 2014). Groundnut is a valuable source of vitamins E, K and B. It is the richest plant source of thiamine (B1) and also rich in niacin, which is low in cereal FAO (2000). Though groundnut is highly palatable and has better binding properties for pelleting than soybean meal (Lovell 1989), its use in fish feed is limited because of low lysine and methionine contents, and inconsistent supply (Robinson & Wilson 1985; Lovell 1989). This study was conducted to replace the fishmeal protein by groundnut protein for Nile tilapia so that cost-effective nutritionally-balanced feeds could be prepared for tilapia intensive culture.

Materials and Methods

Experimental System and Animals

Fingerling *Oreochromis niloticus* were procured from Centeral Inland Fisheries Research Institute, Barrackpore, Kolkata, West Bengal-India. These were transported in oxygen filled polythene bags, to the wet laboratory Department of Zoology, Aligarh Muslim University, Aligarh, India, and given a prophylactic dip in $KMnO_4$ solution (1:3000) and stocked in indoor cylindrical aqua-blue coloured, plastic lined (Plastic Crafts Corp, Mumbai, India, 1.22m in diameter 0.91m in height) fish tanks (water volume 600 L) for a fortnight. During this period, the fish were fed to apparent satiation by feeding diet consisting of mustard oil cake, soybean meal and wheat middling in the form of soft cake twice a day at 0900 and 1730 h.

For conducting the experiment, *Oreochromis niloticus* fingerlings (0.57± 0.02g; 3.49 ± 0.12 cm) were sorted out from the above acclimated lot and stocked in triplicate groups in 70-L circular polyvinyl tanks (water volume 55 L) fitted with a continuous water flow-through (1-1.5 L min-1) system at the rate of 20 fish per tank for each dietary treatment. Fish were fed test diets in the form of soft cake to apparent satiation twice daily at 0900 and 1600h. No feed was offered to the fish on the day they were weighed. Initial and weekly weights were recorded on a top-loading balance (Precisa 120A; 0.1 mg sensitivity, Oerlikon AG, Zurich, Switzerland). The feeding trial lasted for 6 weeks. Faecal matter and unconsumed feed, if any, were siphoned off before every feeding. The unconsumed feed was filtered on a screen soon after active feeding, dried and weighed to measure the amount of feed consumed. External deficiency signs and mortality if any, were examined and recorded.

Diet Formulation and Preparation

The ground nut cake used as protein sources in this study was collected from Aligarh market, India commercial sources. These are; groundnut (*Arach is hypogaea* L.) meal and cottonseed (*Gossypium* spp.) cake (mechanically extracted). All the ingredients (which came as one batch) procured from local market and subjected to proximate analysis. Proximate composition was analyzed before any diet formulation to check the nutritional quality. Control diet containing 35% CP and 16.53 $kJ.g^{-1}$ GE was prepared. These levels are based on requirements for Nile tilapia fry/fingerlings Anderson et al. (1991). Feasibility of replacing fishmeal with ground nut cake for Nile tilapia *O. niloticus* fingerling by were find out by preparing six diets replacing 0% D1, 20% D2, 40% D3, 60% D4, 80% D5, 100% D6 fish meal protein by ground nut cake protein (Table 1). Six isonitrogenous (35% CP) and isocaloric (16.53 $kJ.g^{-1}$) diets were formulated using fish meal, ground nut cake, soybean meal, mustard oil cake and wheat middling. Crude protein content in the diet was fixed at 35% on the basis of earlier available information (Abdelghany, 2000; Niamat and Jafri, 1984). All the ingredients were weighed and blended in a Hobart electric mixer (A-200T Mixier Bench Model unit; Ottawa, Canada) thoroughly. These were then steam cooked at 80°C in a volume of hot water. Oil, mineral and (vitamin premixes were perpared as per Halver (2002), were added to the lukewarm bowl one by one with constant mixing at 60°C. The final diet with bread dough consistency, and then pellets were produced by manual meat grinder with 0.6 mm diameter and later were dried for 24 hrs and subsequently broken into crumbled form and each diet was packed in a plastic bag and stored until used. The proximate composition of the experimental diets used in this experiment were analyzed and are given in Table 1. Amino acid content of experimental diets was analysed using Amino Acid Analyzer (Hitachi L-8800; Tokyo, Japan). Recovery hydrolysis for analysis of tryptophan was performed in 4 N methanesulfonic acid and for sulphur amino acids in performic acid (Table 2). The fatty acid profiles of the experimental diets were analyzed gas liquid chromatography (GLC® Shimadzu GLC Ltd, Japan) and are given in Table 3.

Water quality parameters

Water temperature, dissolved oxygen, free carbon dioxide, pH, and total alkalinity during the feeding trial were recorded following standard methods (APHA 1992). The average water temperature, dissolved oxygen, free carbon dioxide, pH, and total alkalinity over the 6-weeks feeding trial, based on daily measurements, were 25.6-27.7 ºC, 6.6-7.5 mg L^{-1}, 7.1-9.2 mg L^{-1}, 7.2-7.6 and 71- 81.7 mg L^{-1}, respectively.

Proximate composition analyses

At the begining of experiment, 10 fish were euthanized at stocking and frozen (<-15 ºC) for initial whole-body composition analysis, and at the termination of the six weeks feeding trail, all fish were counted and weighted, and 10 fish per trough were ranndomly selected for analysis of whole-body composition. Assessment of proximate composition of ingredients, diets and carcass was made using standard techniques (AOAC 2005). Briefly, crude protein (N x 6.25) was determined (Kejeltec Tecator^{TM} Technology 2300, Sweden), dry matter was determined after drying in a oven at 105 ºC, ash content was determined by incineration in a muffle furnace at 550 ºC for 8 hrs, crude fat (solven extraction with petroleum ether B.P 40-60ºC for 2-4 h Socs Plus, SCS 4, Pleican Equipments, Chennai, India).

Growth Parameters

The effects of replacing fish meal with ground nut cake in diets on growth and conversion efficiency of fingerling *Oreochromis niloticus* during the present experiment was evaluated using following indices:

Absolute weight gain (g fish^{-1}) = Final individual body weight-Initial individual body weight

Live weight gain (LWG; %) = Final individual body weight-Initial individual body weight/Initial individual body weight × 100

Feed conversion ratio (FCR) = Dry feed fed/Wet weight gain

Protein efficiency ratio (PER) = Weight gain/Protein fed

Protein Retention Efficiency= (Final body weight x Final protein)-(Initial body weight x Initial protein)/ Initial Protein * 100

Specific growth rate (SGR; % day^{-1}) = Ln Final body weight-Ln Initial body weight/No. of days × 100

Per cent survival (SR;%) = (Final number of fish/Initial number of fish) × 100

Statistical analysis

All growth data were subjected to one-way analysis of variance (Sokal & Rohlf, 1981). When a significant treatment effect was observed, Tukey's honest significant difference test was used for multiple mean comparisons at a P<0.05 level of significance. Statistical analyses were done using Origin (version 6.1; Origin Software, San Clemente, CA).

Resuts

Growth data generated during this feeding trial are listed in Table 4. In the present study, replacement of fishmeal by groundnut cake on protein to protein basis was found to be feasible up to 20% as evident by insignificant differences among the growth indices such as LWG (463.16 - 441.38%), FCR (1.64 -1.68), PER (1.74 - 1.70) , SGR (3.53 - 3.45 %) in fish fed diets 1 and 2. However, further replacement of fishmeal by groundnut oil cake beyond 20% (diets 3, 4, 5 and 6) resulted in a marked decrease in growth parameters. A 100 % survival was recorded in all the treatments.

Body composition data of the fish fed different diets are given in Table5. No significant differences in moisture content were evident in fish fed diets 1 and 2. However, significant differences in moisture content were evident in fish fed diets 3, 4, 5 and 6. However, body fat showed a reverse pattern to that of moisture content. Body protein remained almost unchanged in fish fed diets 1 and 2 whereas fish fed diets 3, 4, 5 and 6 showed significant (P<0.05) decline in body protein. Insignificant differences (P>0.05) in body ash content were evident in fish fed diets 1 and 2 beyond which significant increase in ash content was evident.

Discussion

Aquaculture feed industries are facing a serious problem of scarcity of its finite protein source such as fish meal. Successful replacement of fish meal by economical protein sources, even in minor quantities from a feed formulation, is desirable as it will obviously reduce the feed cost as well as farm production costs (Akiyama et al., 1995; Amaya et al. 2007; Yıldırım et al.

2014). Nutrition is critical because feed typically represents approximately 50 percent of the variable production cost. Fish nutrition has advanced dramatically in recent years with the development of new, balanced commercial diets that promote optimal fish growth and health (Sidhu and Sidhu 2020). Nutrition forms 70% of the total cost of animal or fish production thus making feed efficiency an important parameter for a successful business (Craig et al., 2017). In the absence of fishmeal, it is important to evaluate the nutritional value of alternative ingredients and formulate diets based on a mixture of ingredients which can collectively replace fishmeal in the diet of fish. Among the many protein sources available for animal feeds, plant proteins appear to be the most appropriate alternatives to fishmeal in fish diets. Partial replacement of fishmeal by plant proteins has been accomplished in many carnivorous cultured fish (Gomes et al. 1995; Kaushik et al. 1995, 2004; Robaina et al. 1995; Masumoto et al. 1996; Fagbenro 1999, 2001; El-saidy and Gaber 1997, 2002; Abeer et al., 2019), but total replacement has met with success in only a few cases (Kaushik et al. 1995; Regost et al. 1999). Among the plant protein sources, legumes are the most promising species (Gouveia and Davies 1998, 2000). However, the use of legumes in aquaculture diets is potentially limited by some inadequacy in their protein composition, relatively high level of carbohydrate and the presence of a variety of anti-nutritional factors (Booth et al. 2001). Legumes are highly valued in feeds for both ruminants and monogastric livestock due to their relatively high protein and energy values (Khorasani and Kennelly1997, Edwards 2000). In view of this, a number of plant and animal protein sources have been used for the replacement of fish meal (Yue and Zhou, 2008; Ju et al., 2012; Macias-Sancho et al., 2014; Ding et al., 2015; Shiu et al., 2015; Sharawy et al., 2016; Yousif et al., 2019 a,b; Shao et al., 2019). Amongst the legumes, groundnut oil cake has been major source of vegetable protein in poultry as well as fish feeds in our country. However, it contains trypsin inhibitor that limits its use. It can be destroyed by mild heating. Therefore, solvent extracted groundnut oil cake is mostly used. Growth reflects the metabolic interactions and adjustments, which are sustained by the nutritional status. In this experiment, replacement of fishmeal by groundnut oil cake on protein to protein basis was found to be feasible up to 20% without compromising growth and feed conversion. However, further replacement of fishmeal by groundnut oil cake beyond 20% resulted in a marked decrease in growth parameters. This reduction in growth may be because of the poor amino acid and fatty acid profile of the experiment diet due to lower amount of fish meal in this diet. This reduction may also be related to poor palatability of groundnut oil cake and the high level of anti-nutritional factor in the groundnut oil cake. The negative effects at high inclusion levels of plant protein sources are well documented from earlier work on trout (Gomes et al. 2004, Torstensen et al. 2008, Sanz et al. 1994**,** Barnes et al. 2014) and other species (Wang et al 2012, Liu et al. 2012a, Walker et al. 2010, Refstie et al. 2001, Opstvedt et al. 2003, Mundheim et al. 2004; Yousif et al. 2019 a,b).

In this study, reduced growth performance and higher feed conversion ratio were recorded in fish fed diets 3, 4, 5 and 6 with 40, 60, 80 and 100% replacement value. This indicates that ground nut cake cannot be used as a high level protein source for *Oreochromis niloticus.* These results are similar to that observed for Davies and Ezenva (2010) in African catfish *Clarias gariepinus*; Ovie and Sie (2007) in *Heterobranchus longifilis* who reported that the feed conversion ratio was increased by increasing percentage of groundnut oil cake as a replacement of fish meal in fish diet; Yıldırım et al. (2014) in Mozambique

Tilapia Fries (*Oreochromis mossambicus*) using Peanut Meal (*Arachis hypogaea*) their results showed that 10% and 20% of fishmeal replaced with grund nut, showed the best growth performance and feed evaluation, and higher dietary FM replacement negatively affected growth performance and feed evaluation; Garduño-Lugo and Olvera-Novoa (2008), successfully replaced 20% of the fish meal diet with peanut leaf meal for Nile tilapia without negative effects on growth performance. Lim (1997) and Liu et al. (2008 b) said that low ground mut inclusion level is possible (104-120 g kg^{-1}) in the diet for Pacific white shrimp. Liu et al. (2012a) who replaced FM with peanut meal in the diet of shrimps and recommended a maximum level of 14% PNM in the diet.

Conclusion

Result from the present experiments indicates that 20% of fish meal protein could be replaced by groundnut meal without altering the growth, conversion efficiencies and body composition of fingerling *Orochromis. niloticus*, respectively. Thus, enabling formulation of cost-effective artificial feeds for the intensive culture of this fish.

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أثر إستبدال مسحوق الأسماك بمسحوق الفول السوداني على النمو . معدل التحول الغذائي والتركيب الكيميائي لأصبعيات أسماك البلطي النيلي

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المستخلص

في هذه الدراسة, اولا تم التحليل التقريبي وتحليل الدهون للمواد التي تم إستخدامها في عليقة الأسماك, ومن ثم دراسة إستبدال مسحوق الأسماك بمسحوق الفول السوداني لأصبعيات أسماك البلطس النيلي بمعدل 0% , 20% , 40% , 60% , 80% و 100% . وتم تخزين الأسماك بمعدل 20 سمكة للحوض الواحد بمعدل 3 تكررات للمعاملة الواحدة. تمت تغذية أصبعيات أسماك البلطي النيلي *Oreochromis niloticus* (0.57±0.02 جم : 3.49±0.12 سم) العلائق التجريبية لمدة 6 أسابيع إلى حد الأشباع. تحتوي هذه العلائق على 35% بروتين خام و 16.53 كيلوجول / جرام طاقة نمو. معدل إستبدال مسحوق الأسماك بمسحوق الفول السوداني بمعدل 20% اظهرت فروق معنوية ($p<0.05$) للوزن المكتسب (2.56±0.05 جم / سمكة) , معدل التحول الغذائي (1.68±0.01) , معدل كفاءة البروتين (1.70±0.02) ومعدل النمو النوعي (3.45±0.02%) للأسماك التي تمت تغذيتها بالعليقة 2 (20%). وهنا تشير النتائج إلى انه في حالة إستخدام معدل إستبدال أعلى من 20% هنالك تدني لهذه المقاييس.

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Table 1. Ingredients composition of experimental diets (35% C.P)

Ingredients (g/ 100 g dry diet)	D 1 (0%)	D 2 (20%)	D 3 (40%)	D 4 (60%)	D 5 (80%)	D6 (100%)
Fish meal[1]	14.71	11.76	8.82	5.88	2.94	0.00
Groundnut cake[2]	0.00	3.85	7.69	11.54	15.38	19.23
Soybean meal[3]	37.78	37.78	37.78	37.78	37.78	37.78
Mustard oil cake[4]	13.51	13.51	13.51	13.51	13.51	13.51
Wheat middling[5]	14.29	14.29	14.29	14.29	14.29	14.29
Cottonseed meal[6]	2.63	2.63	2.63	2.63	2.63	2.63
Mineral premix[7]	2.00	2.00	2.00	2.00	2.00	2.00
Vitamin premix[8]	3.00	3.00	3.00	3.00	3.00	3.00
Sunflower Oil	5.00	5.00	5.00	5.00	5.00	5.00
Cod Liver Oil	2.00	2.00	2.00	2.00	2.00	2.00
Alpha cellulose	5.09	4.19	3,27	2.37	1.47	0.56
Total	100	100	100	100	100	100
Proximate composition of the diet						
Protein (%)	35±0.24	35±0.27	35±0.14	35±0.53	35±0.23	35±0.12
Ether Extract%	7.5±0.02	7.78±0.13	7.23±0.90	7.81±0.20	7.92±0.33	7.72±0.22
Ash (%)	6.99±0.19	7.62±0.19	7.34±0.44	6.82±0.09	6.44±0.04	5.91±0.06
Fiber content (%)	6.89±0.1	6.20±0.4	6.42±0.5	6.47±0.7	6.58±0.2	6.73±0.4
Calculated gross energy (kJ g^{-1}, dry diet)	16.77±0.3	16.07±0.1	16.38±0.1	16.68±0.5	16.98±0.2	16.29±0.5

[1]Fishmeal 68% CP; [2]Ground nut meal 52%;%; [3]Soybean meal 45% CP; [4]Mustard Oil Cake 37; [5]Wheat Middling 14% CP and [6]Cottonseed meal 38%.[7]Mineral mixture (g/100g dry diet) calcium biphosphate 13.57; calcium lactate 32.69; ferric citrate 02.97; magnesium sulphate 13.20; potassium phosphate (dibasic) 23.98; sodium biphosphate 08.72; sodium chloride 04.35; almunium chloride.$6H_2O$ 0.0154; potassium iodide 0.015; cuprous chloride 0.010; mangnous sulphate H_20 0.080; cobalt chloride. $6H_2O$ 0.100; zinc sulphate. $7H_2O$ 0.40 (Halver, 2002). [8]Vitamin mixture (g/100 dry diet) choline chloride 0.500;inositol 0.200; ascorbic acid 0.100; niacin 0.075; calcium pantothenate 0.05; riboflavin 0.02; menadione 0.004; pyridoxine hydrochloride 0.005; thiamin hydrochloride 0.005; folic acid 0.0015; biotin 0.0005; alpha-tocopherol 0.04; vitamin B_{12} 0.00001; Loba Chemie, India (Halver, 2002).

Table 2. Amino acid composition (% dry matter) of the experimental diets.

	Experimental Diets					
	D 1 (0%)	**D 2 (20%)**	**D 3 (40%)**	**D 4 (60%)**	**D 5 (80%)**	**D6 (100%)**
Arginine, %	2.78±0.02	2.71±0.04	2.64±0.02	2.57±0.03	2.50±0.01	2.42±0.01
Histidine, %	1.02±0.01^{a}	0.98±0.01^{b}	0.95±0.03^{b}	0.91±0.01^{bc}	0.87±0.02^{c}	0.84±0.02^{d}
Isoleucine %	1.49±0.01^{a}	1.43±0.03^{a}	1.36±0.01^{b}	1.30±0.02^{b}	1.23±0.01^{c}	1.17±0.02^{c}
Leucine %	2.57±0.02^{a}	2.48±0.01^{ab}	2.38±0.02^{b}	2.29±0.01^{c}	2.19±0.1^{d}	2.09±0.03^{e}
Lysine %	2.31±0.01^{a}	2.19±0.04^{a}	2.08±0.3^{b}	1.96±0.02^{c}	1.85±0.01^{d}	1.74±0.02^{e}
Methionine %	0.71±0.03^{a}	0.65±0.01^{b}	0.58±0.02^{c}	0.52±0.02^{d}	0.45±0.01^{e}	0.39±0.01^{e}
Cystine %	0.31±0.02^{c}	0.33±0.01^{b}	0.35±0.01^{b}	0.37±0.02^{ab}	0.39±0.01^{a}	0.41±0.01^{a}
Phenylalnine %	1.59±0.01^{a}	1.53±0.04^{a}	1.47±0.03^{b}	1.40±0.01^{c}	1.34±0.02^{d}	1.28±0.1^{e}
Tyrosine %	1.44±0.2^{a}	1.37±0.04^{b}	1.30±0.01^{c}	1.24±0.01^{d}	1.17±0.02^{e}	1.10±0.03^{f}
Threonine %	1.39±0.01^{a}	1.33±0.02^{ab}	1.27±0.01^{b}	1.21±0.04^{b}	1.15±0.05^{c}	1.09±0.02^{d}
Tryptophan %	0.28±0.04	0.29±0.03	0.30±0.01	0.31±0.01	0.32±0.02	0.33±0.02
Valine %	1.82±0.01^{a}	1.76±0.05^{a}	1.71±0.02^{bc}	1.65±0.04^{c}	1.60±0.02^{c}	1.54±0.01^{d}

[1]Mean values of 3 replicates±SEM; [2]Not statistically significant (P>0.05)

Table 3. Fatty acids Profile of the experimental diets

	Experimental Diets						
Fatty acid Profile		**D 1 (0%)**	**D 2 (20%)**	**D 3 (40%)**	**D 4 (60%)**	**D 5 (80%)**	**D6 (100%)**
Sat							
Myristic	14:0	0.86±0.02^{a}	0.71±0.01^{b}	0.57±0.02^{bc}	0.43±0.05^{c}	0.29±0.02^{d}	0.14±0.03^{e}
Palmitic acid	16:0	7.18±0.3^{a}	7.13±0.2^{b}	7.09±0.1^{b}	7.04±0.2^{bc}	6.99±0.1^{c}	6.95±0.6^{c}
Stearic acid	18:0		2.33±0.4	2.31±0.2	2.28±0.3	2.25±0.6	2.23±0.1
Mon							
Palmitoleic acid	16:1 n-7	1.35±0.05^{a}	1.15±0.04^{a}	0.95±0.01^{b}	0.75±0.05^{bc}	0.55±0.02^{c}	0.35±0.03^{c}
Oleic acid	18:1 n-9	13.83±0.7^{d}	14.92±0.9^{c}	16.01±0.4^{bc}	17.10±0.3^{b}	18.19±0.2^{a}	19.28±0.8^{a}
Gadoleic acid	20:1 n-11	1.28±0.04^{a}	1.12±0.02^{b}	0.96±0.2^{b}	0.80±0.1^{c}	0.64±0.1^{d}	0.47±01^{e}
Erucic acid	22:1 n-9	1.07±0.05^{a}	0.88±0.03^{b}	0.68±0.01^{c}	0.49±0.02^{cd}	0.30±0.01^{d}	0.10±0.02^{e}
n-3 LC-PUFA							
Linoleic acid (LA)	18:2 n-6	25.08±0.6^{d}	26.13±0.7^{c}	27.18±0.8^{bc}	28.24±0.5^{b}	29.29±0.4^{a}	30.35±0.3^{a}
Gamma-Linolenic acid (GLA)	18:3 n-6	0.03±0.02	0.02±0.01	0.02±0.01	0.02±0.00	0.02±0.00	0.01±0.00
Arachidonic acid	20:4 n-6	0.13±0.02	0.11±0.03	0.09±0.05	0.07±0.04	0.05±0.03	0.03±0.01
Alpha-Linolenic acid (ALA)	18:3 n-3	2.82±0.2	2.77±0.2	2.73±0.5	2.68±0.6	2.63±0.5	2.59±0.7
Stearidonic acid	18:4 n-3	0.30±0.02^{a}	0.25±0.01^{ab}	0.20±0.01^{b}	0.15±0.03^{c}	0.10±0.01^{d}	0.05±0.01^{e}
Eicosapentaenoic acid (EPA)	20:5 n-3	1.36±0.04^{a}	1.13±0.02^{b}	0.90±0.01^{c}	0.68±0.01^{d}	0.45±0.01^{de}	0.22±0.02^{e}
Docosapentaenoic acid (DPA)	22:5 n-3	0.52±0.01^{a}	0.42±0.02^{b}	0.33±0.02^{c}	0.24±0.01^{d}	0.14±0.02^{e}	0.05±0.01^{f}
Docosahexaenoic acid (DHA)	22:6 n-3	1.80±0.01^{a}	1.51±0.03^{ab}	1.22±0.01^{b}	0.94±0.04^{c}	0.65±0.02^{d}	0.36±0.01^{e}

[1]Mean values of 3 replicates±SEM; [2]Not statistically significant (P>0.05)

Table 4. Growth and conversion efficiencies, of fingerling *Oreochromis niloticus* fed ground nut cake based diet

	Varying replacement levels of fish meal by ground nut cake (%)					
	D 1 (0%)	**D 2 (20%)**	**D 3 (40%)**	**D 4 (60%)**	**D 5 (80%)**	**D6 (100%)**
Initial weight (g/fish)[1,2]	0.57±0.01	0.57±0.03	0.57±0.01	0.57±0.02	0.57±0.02	0.57±0.01
Final weight (g/fish)[1,2]	3.21±0.01[a]	3.14±0.02[a]	2.71±0.05[b]	2.31±0.09[c]	1.93±0.06[d]	1.49±0.05[e]
Absolute weight gain (g/fish)[1,2]	2.64±0.06[a]	2.56±0.05[a]	2.14±0.02[b]	1.74±0.03[c]	1.36±0.04[d]	0.92±0.03[e]
Live weight gain (%)[,2]	463.16±0.4[a]	441.38±0.9[a]	375.44±0.3[b]	305.26±0.5	238.60±0.7	161.40±0.6
Protein retention efficiency (%)[1,2]	30.63±0.1[a]	29.07±0.3[a]	25.75±0.3[b]	18.10±0.5[c]	13.18±0.8[d]	7.97±0.4[e]
Protein gain (g/fish)	0.47±0.01[a]	0.44±0.01[a]	0.36±0.02[ab]	0.27±0.02[b]	0.18±0.01[c]	0.11±0.02[d]
Specific growth rate (%/day)	3.53±0.01[a]	3.45±0.02[a]	3.18±0.01[a]	2.86±0.01[ab]	2.49±0.03[b]	1.96±0.03[c]
Feed conversion ratio	1.64±0.02[e]	1.68±0.01[d]	1.87±0.01[c]	2.47±0.01[b]	2.94±0.01[b]	4.35±0.03[a]
Feed intake (mg $fish^{-1}$ day^{-1})	4.30±0.02	4.30±0.02	4.20±0.03	4.30±0.05	4.29±0.02	4.20±0.01
Protein efficiency ratio	1.74±0.02[a]	1.70±0.02[a]	1.53±0.01[b]	1.16±0.03[c]	0.97±0.01[d]	0.66±0.03[e]

[1]Mean values of 3 replicates ± SEM.

[2]Mean values sharing the same superscripts are insignificantly different ($P > 0.05$)

Table 5. Carcass composition (%wet basis) and survival of fingerling *Oreochromis niloticus* fed diets containing varying replacement levels of fish meal by ground nut cake [1,2]

	Varying replacement levels of fish meal by ground nut cake (%)						
	Initial	**D 1 (0%)**	**D 2 (20%)**	**D 3 (40%)**	**D 4 (60%)**	**D 5 (80%)**	**D 6 (100%)**
Moisture (%)	74.77±0.41	77.11±0.23[a]	77.43±0.31[a]	76.1±0.15[ab]	75.36±0.27[b]	74.21±0.77[c]	73.11±0.25[d]
Crude protein (%)	12.48±0.10	16.71±0.15[a]	16.24±0.12[a]	15.93±0.16[b]	14.87±0.21[c]	13.25±0.16[d]	14.19±0.15[e]
Crude fat (%)	3.47±0.35	3.45±0.13[d]	3.41±0.15[d]	3.92±0.17[c]	4.61±0.20[b]	4.91±0.23[b]	5.45±0.14[a]
Ash (%)	2.17±0.01	2.19±0.01	2.20±0.03	2.19±0.02	2.21±0.03	2.16±0.01	2.18±0.02
Survival (%)	-	100	100	100	100	100	100

[1] Mean values of 3 replicates±SEM; [2]Not statistically significant (P>0.05).